

Route choice and residential environment: introducing liveability requirements in navigation systems in Flanders



Koen De Baets^{a,b}, Sven Vlassenroot^{a,c}, Kobe Boussauw^{a,b,*}, Dirk Lauwers^a, Georges Allaert^a, Philippe De Maeyer^b

^a Centre for Mobility and Spatial Planning (AMRP), Institute for Sustainable Mobility (IDM) – Ghent University, Vrijdagmarkt 10/301, 9000 Ghent, Belgium

^b Department of Geography – Ghent University, Krijgslaan 281, 9000 Ghent, Belgium

^c Flanders Institute for Mobility, Wetenschapspark 13, 3590 Diepenbeek, Belgium

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ABSTRACT

Vehicle route planning and navigation systems aim to provide the most beneficial routes to their users while disregarding the impact on the liveability of the surrounding residential areas. Therefore, future integration of route choice behaviour by route planners and measures to improve liveability and safety standards should be pursued. The Spatial Plan for Flanders, which is the overarching spatial policy plan in the northern part of Belgium, determines a system of road categories aimed at optimising the liveability of sensitive areas, such as residential neighbourhoods or school precincts, without jeopardizing accessibility. This paper examines to what extent routes proposed by commercial route planners differ from more socially desirable routes that are guided by the policy principles of road categorisation in Flanders as proposed by the plan. Results show that commercial route-planners' routes choose more often roads of the lowest category than socially acceptable. However, for some of the assessed connections, the socially desired alternative is a feasible route as well, which is not excessively increasing time consumption or distance travelled. It is concluded that the implementation of the prevailing road categorisation system in Flanders in routing algorithms has the potential to promote more sustainable route choices, while infrastructural measures that discourage cut-through traffic may help materialising the categorisation system.

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1. Introduction

In recent years, route planners and navigation systems have become standard attributes for the Western motorist. Commercial route planning systems aim to provide the fastest or the most efficient route between two user-specified addresses. In 95% of all cases, navigation aid is used to take the user to an unfamiliar destination, although there is even a minority which uses navigation while heading to familiar destinations (Van Rooijen et al., 2008). Accurate mapping of the achievable speed on the entire road network, in combination with shortest path algorithms allow modern route planners even to offer an optimised route choice solution for a trip that was already known by the user. A human actor will

follow his or her intuition, which is usually based on the hierarchy of the road network as it occurs in the mental map of the driver (Car and Frank, 1994). This means that such a user has no access to the complete network information, and is therefore obliged to exclude a number of possible routes beforehand. Also in the case where the driver would use a printed street map, the problem of incomplete information is still present. A route planner, however, is a powerful tool that calculates the fastest possible route in a rational way, not avoiding local roads whenever use of these would lead to shorter travel time. But the dominant use of navigation gives also rise to potential harm, facilitating cut-through traffic and associated liveability problems of neighbourhoods, village centres and school precincts. Besides, such problems are not limited to car traffic, but are even more severe in the case of freight transport. Trucks do not only cause more pollution than cars do, they are also more often heading to unknown destinations, while using almost always an on-board navigation system.

So, we hypothesise that parallel optimisation of individual route choices leads to suboptimal solutions for the system as a whole. This problem was recognised long before the general use of route

* Corresponding author at: Centre for Mobility and Spatial Planning (AMRP), Institute for Sustainable Mobility (IDM) – Ghent University, Vrijdagmarkt 10/301, 9000 Ghent, Belgium. Tel.: +32 9 331 32 56.

E-mail addresses: koen.debaets@ugent.be (K. De Baets), svenvlassenroot@vim.be (S. Vlassenroot), kobe.boussauw@ugent.be (K. Boussauw), dirk.lauwers@ugent.be (D. Lauwers), georges.allaert@ugent.be (G. Allaert), philippe.demaeyer@ugent.be (P. De Maeyer).

planners, primarily in the context of congestion problems, but also in relation to liveability and safety threats. In the past, governments have often anticipated socially undesirable route choice through appropriate signposting (Akçelik and Maher, 1977; Wright, 1978). Research into signposting methods has been followed recently by a new line of inquiry on dynamic traffic signalisation (Taale, 2008). Nevertheless, hardly any literature can be found about the consequences of the introduction of in-vehicle navigation systems on travel behaviour. The link between navigation system based route choice and liveability is not even addressed at all in the academic literature, although a number of authors, such as Ericsson et al. (2006), point out opportunities regarding travel efficiency optimisation in terms of energy consumption or emissions. Hoogendoorn et al. (2011), is one of the few scholars who outlines a perspective in which individual navigation could be influenced aiming at a better functioning of the traffic system as a whole.

Departing from the identified research gap, the present study is an exploratory investigation intended to gaining insight into the difference between route choice behaviour of car navigation systems, and route choice according to scenario that have been developed by urban and mobility planners. Based on a limited number of case studies, lessons are learned and policy recommendations are developed, aimed at preventing through traffic in environments where this is undesirable. We do so by comparing the route choice of a number of commercial route planners with a route that would be in line with the requirements of the Spatial Plan for Flanders (SPF), which is the overarching spatial policy plan in the northern part of Belgium.

2. The difficult choice between fast and socially desired

Although developers of route planners realise that the fastest route is not necessarily the most responsible choice, their paramount interest remains in serving their own customers. Consequently, truthful information is recorded in digital maps as much as possible, and is supplemented by legal conditions. As long as it is not illegal to use a given street, it will be included in the map as a possible link.

However, the reasoning behind the road categorisation system that was introduced in SPF and consequently applied in provincial and municipal policy plans, is different. Road categorisation is based on the principle that the major part of an itinerary should follow a road, which is ranked as high as possible in the designed hierarchy, even if this would entail a significant detour. In this way, nuisance caused by cut-through traffic would be minimised. Below we will illustrate the difference between commercial route planner behaviour and policy based route guidance.

2.1. Route planner approach

Route planners calculate an optimal itinerary between two locations, depending on the available data. Route calculation relies on a road map enriched with additional information to guide vehicles efficiently through the road network, and on an algorithm to calculate a suitable route based on the available data.

2.1.1. Map database

Data needed for route planning are structured as a digital map. Such a map is a geospatial database (Güting, 1994), which is optimised to store and query spatial data such as road networks. Map makers collect and receive geospatial information, store and process it in a local database, and provide their maps to the end users, i.e. the navigation system vendors. The delivery of spatial data from source to end-user is referred to as a 'data (update) delivery chain'.

Mapmakers' databases contain the geometry of the road network, the road classification¹, characteristics of roads, such as direction. Mapmakers construct this database by collecting their own data or receive data from third parties (Rennemo et al., 2008). Data can be derived from topographic maps, aerial photographs or satellite images. Additional data are collected by fieldwork (Chen et al., 2009; Tao, 2000). Such fieldwork enables to verify parameters, such as narrow passages, one-way streets, street names, signposting, number of lanes, geometry of roads, physical barriers, obscure locations, and inaccessible roads. Other data are obtained from various institutions, mostly regional or municipal authorities. For example, a municipality can inform a mapmaker of (physical) modifications in the road network or the addition of new traffic signs. Such applicable data are transferred to the mapmakers, and consequently processed and stored in the databases.

The next step in the data provision chain is delivering the maps to the navigation system and to route planner developers. Mapmakers' databases are not designed to be used directly by applications. Such databases are organised for efficient storage and management of digital map data, but are not compact enough for use in navigation devices and not suitable for fast calculation of routes. Therefore, suppliers of navigation systems will compile the database in order to obtain a file system, which meets the needs of the navigation device. Such custom map databases are referred to as a physical storage format (PSF), and may differ among vendors of navigation devices.

Apart from traditional static maps, systems handling real-time data are in full development, and are already used by the latest version of some route planners. But since most navigation systems that are in use in Belgium, take not yet account of real-time traffic information, the scope of our research is limited to static route planners.

2.1.2. Algorithm

A routing algorithm is in charge of an efficient and up-to-date route calculation, taking into account a whole range of predefined network properties that jointly represent a travel cost per kilometre. The algorithm finds the optimal route through minimising the total travel cost.

One of the main algorithms to calculate routes is the Dijkstra's shortest path algorithm (Dijkstra, 1959). The algorithm searches for the lowest cost path between a node and every other node in the network. This process is labour-intensive and delivers lots of redundant results. While planning a route, the general direction of the route is known in advance (Fu et al., 2006). This knowledge allows to search for results in a limited area and can be used to accelerate the search process. A* is an algorithm (Koenig et al., 2004) that applies this principle, and is widely used in route planners and navigation systems. The calculation can be further accelerated by applying bidirectional search, in which case the algorithm simultaneously searches from origin towards destination and from destination towards the origin. So, these two searches will meet somewhere in between. Furthermore, road networks are often modelled according to a hierarchical structure. This has introduced the idea of an efficient, hierarchical search algorithm for road networks. The basic idea is to search in an abstract area in the first place, rather than in the entire area. Such an abstract area can be demarcated for each hierarchical level. This allows an incomplete first route search at the upper level in the hierarchy. Next, details can be added using roads from a lower level. In a large road network it is recommended to apply a heuristic, bidirectional and hierarchical search method (Zhao, 1997).

¹ In this paper, the term "road classification" refers to the technical hierarchy that is used in route planner maps, while the term "road categorisation" refers to the desired hierarchy as introduced by SPF. The present research will clarify that significant differences exist between class and category.

Depending on the preferences of the user, navigation systems and route planners offer various routing options to select an itinerary. Changing the preferred routing options will influence the use of different parameters while calculating a route. This allows route planners to suggest multiple routes between two locations. The most common option is the fastest route, but alternatives are available such as the shortest, the most fuel efficient (Ericsson et al., 2006), and the safest route possibly depending on the time of day (e.g. school hours) (Schäfer, 2009). In the end, it is up to the end user to make the choice.

2.2. Socially desired route choice approach

Route planner developers aim to create a digital map as a true representation of the road network, including all necessary legal conditions to avoid traffic violations. Within these limits, navigation systems are entirely free to recommend any route. From a liveability perspective, however, drivers should be guided to particular roads and directions (Kloster et al., 1999). In Flanders, such a strategy is specified in spatial policy plans and mobility policy plans, which state that relations between particular destinations should run via certain routes that are suitable for the associated traffic loads. Such routes are defined through categorisation of the roads. Road categorisation aims at organising traffic flows and at discouraging cut-through traffic and associated adverse effects on nearby neighbourhoods, such as pollution, noise, and safety problems.

However, manufacturers of navigation systems have no commercial interest in the implementation of liveability criteria in their systems. Based on our research, we will develop two pathways for encouraging route choice based on liveability criteria. The first line of thought will be based on adapting road design, while a second logic will depart from a certification system of maps that are used by navigation system.

3. Road categorisation in flanders

In Flanders, in the nineties a fairly complex system of road categorisation was developed by the government, intended to re-organise the use of the traffic network. Within a partnership of regional, provincial, and municipal authorities, a hierarchical system was developed in which each road was assigned to a particular category (Lauwers, 2008). Each category corresponds to a well-defined desired road design and a specific type of traffic. Roads of the highest category ("main roads") are supposed to be developed into full-fledged motorways without intersections, with the intention of attracting long-distance traffic. Roads of the lowest category ("local roads of type III") will be redesigned in a way that discourages through traffic, with the intention of enhancing the liveability of such streets for residents. This categorisation system is viewed as a tool to implement a spatial vision, and was determined in the SPF (RSV, 1997/2004; Scheers, 2006). However, the rate at which the layout of the infrastructure involved is adapted to this long-term vision depends on many factors, including political priorities and budget allocation. Meanwhile, cut-through traffic on local roads worsens, due to the widespread use of navigation systems.

Categorisation introduces a policy-oriented hierarchy in the road system. It allows defining and subdividing complex road networks, and clarifies the structure of the road network for both road users and road administrators. Matena et al. (2006) distinguish three methods to assign roads to road categories; the so-called hierarchical categorisation, the categorisation by road types, and the functional categorisation.

What Matena et al. (2006) call hierarchical categorisation is actually an administrative classification used to allocate

competences regarding the construction, maintenance and management of various road networks among authority levels, such as the central government, regions or municipalities. Categorisation by type of road refers to the geometry, the design and bearing capacity of the road. This form of categorisation is often used as a basis for setting speed limits. The third method, called functional road categorisation, is based on transportation planning purposes, where the function of the road is situated on a continuum between providing access and connecting. Roads of the lowest category (access roads) should primarily provide access to individual lots or buildings, and therefore have no connecting function. Roads of the highest category (connector roads) have a regional or even an international connecting function and do not provide direct access to road networks at the bottom of the hierarchy. The general category between access road and connector road is called collector road, which collects and channels traffic from access roads to the connector roads. The design of a collector road seeks to limit the number of individual accesses and intersections.

In Flanders the framework proposed by SPF is a form of functional road categorisation consisting of no less than nine categories, which are grouped into four main categories. The four main categories are main roads, primary roads, secondary roads and local roads. Subcategories are distinguished within the categories of primary roads (I and II), secondary roads (I, II and III) and local roads (I, II and III). Main roads have an internationally connecting function, while local roads of type III only provide individual access. The other categories have a collector function to a greater or lesser extent, where the various subcategories indicate specific requirements relating to public transportation or freight transportation. The lower a road is in the hierarchy, the more importance is assigned to the liveability of the environment in which the road is situated (RSV, 1997/2004). Fig. 1 provides a sample of the road network in the study area southeast of the city of Antwerp. The legend indicates which roads were assigned to the categories listed.

Apart from the road system, SPF also distinguishes between different categories and subcategories of settlements. In hierarchical order, the following categories are defined: metropolitan area, regional urban area, small urban area (at subregional level (I), and at provincial level (II)), main village (I, II and III), and small village. Depending on the category of the connected settlements, a higher or lower road category is deemed fit or unfit to carry the traffic flow between these two settlements. Again, subcategories were created, for example, to distinguish between municipalities that are allowed or even encouraged to expand, e.g. by establishing an additional business park, and municipalities that should not.

At the highest level, the road network must be consistent. Roads of regional and subregional level are not required to form an autonomous network, although these are required to form a consistent road network by complementing the higher level network. Consequently all roads are assigned to a tree-like structure with branches to lower level roads and meshes composed of higher level roads. Lower level roads are not supposed to provide links inside meshes that are made up by higher level roads (Lauwers, 2008). The traffic flow at various levels must be in proportion, so that the lower levelled road network does not get overloaded by long distance traffic ('cut-through traffic') and that the road network of higher level is not loaded with local traffic ('illegitimate use').

4. Comparing route choices

4.1. Method

In this paper we simulate an as yet non-existent route planner that applies the hierarchical system of road categorisation according to SPF. By assigning judiciously selected weights to the various

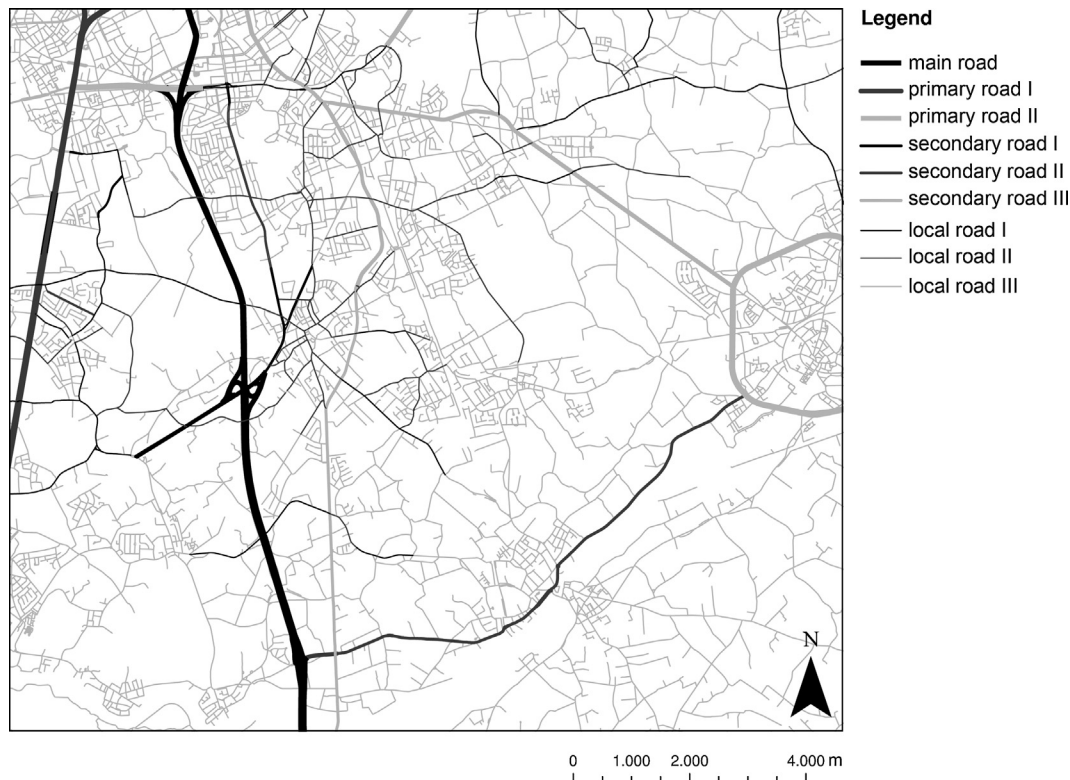


Fig. 1. Sample of categorised roads in the region southeast of Antwerp.

road categories, a liveability factor is introduced in the route choice process. Then, based on a sample of origin-destination pairs, we compare a number of route choices according to the SPF system with itineraries chosen by a number of commercial route planners. Based on the comparison, we evaluate how route choice behaviour could take into account liveability requirements. Hereby three partially complementary approaches can be considered. Firstly the process of redesigning roads in accordance with the assigned category could be accelerated in order to attract or discourage certain types of traffic in a more rigorous way. Secondly developers of route planning systems may be required by law not to send through traffic along local roads. Thirdly the current road categorisation system could be adapted, making it more in line with expected route choice behaviour by drivers.

The aim of this study is to determine to what extent the routes proposed by commonly used route planners in Flanders deviate from the desired way of functioning of the road network, as determined by the SPF principles. For this purpose several routes based on various origin-destination pairs generated by route planners are compared to corresponding 'desired' routes, which take into account the SPF principles. We first present the origins and destinations, after which the route calculation will be discussed. Finally we will compare and evaluate the obtained itineraries.

4.2. Choice of origins and destinations

For the test routes, a sample of representative origin-destination pairs was chosen, based on daily trips between traffic-producing locations and existing relations between settlements. Although car navigation systems are used primarily for trips to unknown destinations (Van Rooijen et al., 2008), this study will focus on a selection of frequently used routes to evaluate the route planners. Road categorisation according to SPF is based on a three level hierarchy of relations: international connections, regional connections and subregional connections. This hierarchy is taken into account

as a starting point for selecting appropriate routes. Due to the limited size of the study area, which consists of the urban fringe south of the city of Antwerp, the focus will be on the connections at the subregional level. The selection of origins and destinations of test routes is based on the settlement category of the locations and on the extent to which locations operate as a traffic generating or attracting area.

An origin-destination matrix illustrates the occurring relations between different settlement categories. Relations at regional level exist between metropolitan areas, between regional urban areas, and between metropolitan and regional urban areas. Relations at subregional level exist between small urban and regional urban areas or metropolitan areas, and among small urban areas themselves. Table 1 provides an example matrix, including relations occurring in the study area.

Apart from relations between settlement categories, attraction centres are chosen for the selection of test routes. These mainly involve economic centres, recreation areas, multi-modal transfer points, train stations, Park & Ride – facilities and event centres in relation to their hinterland. Attraction poles of regional importance are most often industrial parks with lots of commuter and truck traffic. In the study area locations with traffic generating functions of regional importance are selected.

In addition to the selection of settlements and attraction centres, observed traffic flows in the study area are taken into account in the choice of the tested origin-destination pairs. Observed commuter trips show mainly radial connections to Antwerp, but also a non-negligible amount of tangential trips.

Finally the selection of tested origin-destination pairs is also based on trip distance. According to the Travel Behaviour Survey for Flanders (Zwerts and Nuyts, 2004), the average commuting distance is 19 km. This measure is used as a guideline while selecting the tested origin-destination pairs. This selection was completed with a set of typical commuter trips between the urban fringe and the city, which are common in the Antwerp region. By

Table 1
Origin-destination matrix.

Settlement Structure	Metropolitan area	Regional urban area	Small urban area at subregional level	Small urban area at provincial level	Main village type I	Main village type II	Main village type III	Small village
Metropolitan area	/							
Regional urban area	/	/						
Small urban area at subregional level	Antwerpen-Lier	Mechelen-Lier	/					
Small urban area at provincial level	Antwerpen-Boom	Mechelen-Boom	Lier-Boom	/				
Main village type I	Antwerpen-Duffel	/	/	/	/			
Main village type II	Antwerpen-Ranst	Mechelen-Ranst	Lier-Ranst	Boom-Ranst	/	Ranst-Berlaar		
Main village type III	Antwerpen-Zandhoven	Zandhoven-Mechelen	Lier-Zandhoven	/	/	Ranst-Zandhoven	/	
Small village	Antwerpen-Hove	/	Lier-Aartselaar	Boom-Wijnegem	/	Ranst-Wilrijk	Zandhoven-Wijnegem	Aartselaar-Kontich

/ = relation not available in study area.

applying the above stated principles, 11 origin-destination pairs in total were selected within the study area for the calculation of test routes. These routes represent commuter trips and trips to attraction centres of regional importance, and between several categories of settlements.

4.3. Calculation of routes

4.3.1. Commercial route planners

The study uses three commercial Internet based route planners (Google Maps, TomTom, and Mappy) to calculate routes between origin-destination pairs. Each time the first proposed fastest route under basic car navigation settings is considered for our research. Highways and toll roads are not avoided, and other additional functions such as delay reducing tools, or specified time of departure are unchecked for this research. It should also be noted that small changes (no more than 10 m) in origin or destination could greatly alter the calculated route, which required the use of XY coordinates ensuring the comparability of routes.

The routes calculated with the three commercial route planners are then analysed in terms of the SPF road categorisation system. Hereto a base map of the study area has been built in the ArcGIS GIS package, which assigns the categories of the various prevailing municipal, provincial and regional policy plans as an attribute to each network link. Subsequently through a Google Maps work-around, the routes used by the three commercial route planners have been exported to a GPX file, which was eventually imported into ArcGIS (Fig. 1). The ArcGIS Network Analyst tool allows to fit these routes into the categorised network, and to calculate the used share of each road category. This software package uses Dijkstra's shortest path algorithm, applying weights in order to adapt the impedance of the road segments to the SPF road categorisation.

4.3.2. Socially desired route choice

The routes calculated by the commercial route planners will be compared to a 'socially desired' route that takes into account the road categorisation according to the SPF principles. Regarding the network intersections, we distinguish between 'nodes' and 'linking points'. In a node roads of the same level join and the possibility of changing roads exists. In a linking point roads of different levels join with the possibility of changing levels while changing roads. This type of network follows a tree-like structure. Under these conditions we have developed a routing process based on the SPF principles, which follows a structural progression of road use: the route departs from the origin which is usually located on a low category road, and gradually moves to the nearest higher category road until

the highest available category on the connection is attained. While approaching the destination, categories of the used roads gradually decrease. The profile of an exemplary SPF route will therefore be represented by the pattern shown in Fig. 3, in which the origin is represented on the left side, and the destination on the right side.

Like the commercial route planners, SPF routes are calculated through a shortest path algorithm, which in this case is implemented in the Network Analyst tool. In this context the 'shortest path' can be defined as the path with the lowest resistance. Values representing resistance variables are obtained from the network database. This variable to be minimised can be time, distance or any other characteristic assigned to the network. In order to calculate an SPF route, the 'shortest path' is defined as the route with the shortest distance dependent on the used road categories. Hereto the distance of each road link is multiplied by a weight factor.

In the SPF, the road categorisation hierarchy is considered a guideline for desired route choice behaviour. Thus, the applied weight factors were calibrated in order to simulate desired route choice behaviour as outlined in the SPF. For example, SPF indicates that it is preferred that non-local trips use "main roads" as often as possible, at least as long as the detour factor does not exceed 1.4. The weights used in our study have been determined through a process of trial-and-error, in which we have evaluated the various resulting route choice behaviour patterns on the basis of conformity with the SPF's nature. (Table 2).

4.4. Comparison of routes

Although the commercial route planners assessed in this study all rely on the same map database (provided by the company Tele Atlas), the divergent results between route planners suggest a different implementation of the available data. Due to a different approach of data application and the use of alternative algorithms,

Table 2
Assigned weight factors.

Road category	Weight factor
Main road	1.0
Primary road I	1.2
Primary road II	1.2
Secondary road I	1.4
Secondary road II	1.4
Secondary road III	1.4
Local roads I	1.6
Local roads II	1.6
Local roads III	2.0

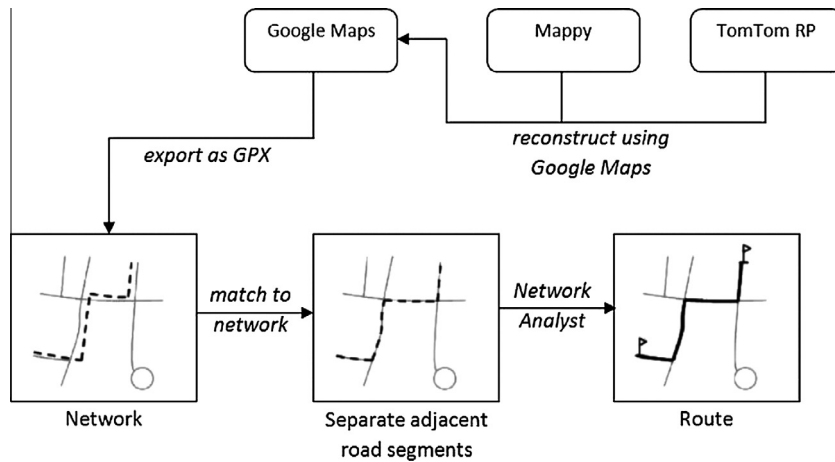


Fig. 2. Processing of routes from route planner to GIS.

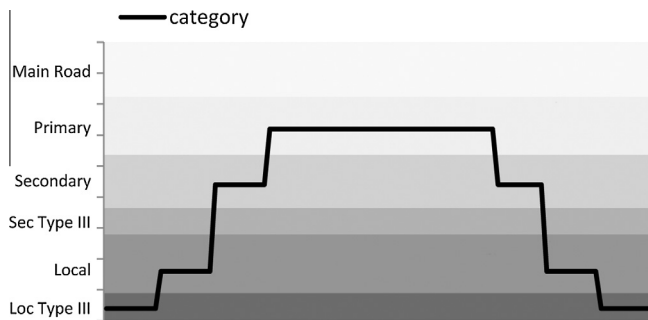


Fig. 3. Profile of an exemplary SPF route.

it is not surprising that various route planners suggest different routes. Our research focuses on detecting conformity of these routes with the corresponding socially desired SPF route. This is done by analysing route profiles in terms of road categories and comparing these with the profile of the socially desired route (as illustrated by Fig. 2). Route profiles indicate where itineraries use lower category roads (legitimate or illegitimate) and where cut-through traffic occurs.

For each origin-destination pair an SPF route is calculated. Next, the three itineraries devised by the route planners are compared with the corresponding SPF routes regarding distance (calculated in ArcGIS Network Analyst) and time (calculated using Google Maps). Both total distance and distance by road category are taken into consideration. The additional distance to be travelled because of detours of the SPF routes should stay within reasonable margins. The tree-like structure of the road network and the road categorisation is defined in such way that policy-based, socially desired, routes (SPF routes) should not result in major detours. The acceptability of a detour can be easily calculated using the following formula: $[shortest\ route] \times [detour\ factor]$. The maximum acceptable detour factor that is suggested by SPF is 1.4 (RSV, 1997/2004).

5. Results

While discussing the results, the applied commercial route planners will be referred to as RP A, RP B and RP C as this study does not intend to evaluate route planners individually.

5.1. The shortest or the fastest route?

The study shows that the average distance of routes generated by the three route planners is 17.6 km, while the in-between

distance deviates on average 10.4%. The SPF routes are on average 6.5% longer than routes suggested by commercial route planners, which corresponds to approximately 1.1 km out of a total average distance of 17.6 km. This shows that in most cases SPF routes do not exceed the maximum acceptable detour (shortest distance $\times 1.4$), as was expected from the structure of the road network.

Fig. 4 shows the percentage of deviation between the three commercial route planners' routes (1–22) compared to the corresponding SPF route. Ratios are calculated as follows:

$$\frac{Dist_{RP} - dist_{SPF}}{dist_{SPF}} \times 100.$$

Positive values imply that the route planners' route is longer than the SPF route. The appearance of a majority of RP-markers below the SPF line in the plot confirms that most routes calculated by commercial route planners are shorter than their SPF counterpart. For 9 out of 22 routes the deviation is smaller than 4% compared to the SPF route. This implies that for the other 13 routes at least one route planner will suggest a route with a distance deviation amounting to more than 4%. Four of these exceed the maximum allowed detour factor and should therefore be considered as unsuitable alternatives. However, in some cases the commercial route planners too exceed these limits (routes 12, 17, 18), which could indicate a deficiency of the road network.

The time difference between the routes is acceptable. Fig. 5 shows the deviation of the three commercial route planners' routes (1–22), compared to the corresponding SPF route regarding trip

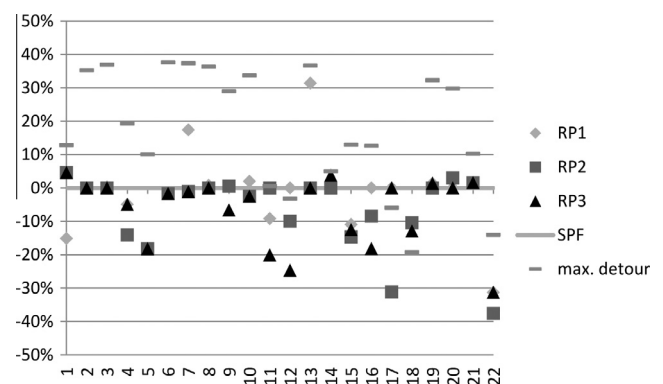


Fig. 4. Deviation of distance of commercial route planners' routes versus SPF routes.

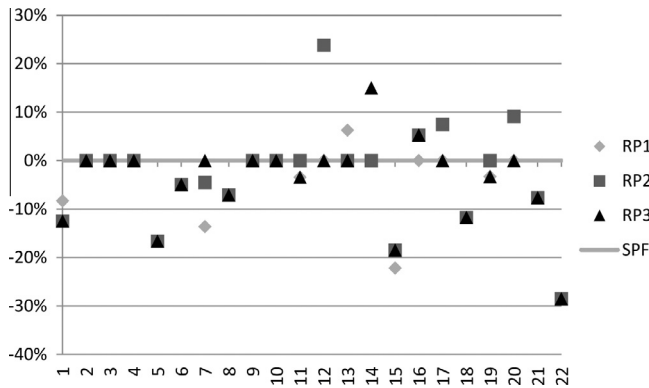


Fig. 5. Time difference between commercial route planners' routes versus SPF routes.

duration (in %). The average time to cover a route using commercial route planners is 19.9 min, while SPF routes take 20.9 min. Hence, the average time deviation is 9.7%. Most SPF routes in our study show longer durations, with a maximum additional time consumption of 6 min (29%) on a 15-min trip (route 22).

5.2. Use of road categories

The principle of road categorisation and the resulting socially desired routes aim at limiting the use of roads of the lower categories. The results reflect this principle. SPF routes make less use of local roads (21%) compared to the routes proposed by the commercial route planners (27%) (measured by kilometres travelled). The use of secondary roads (20% for route planners and 23% for SPF routes) and primary roads (23% for route planners and 21% for SPF routes) shows the lowest variance. SPF routes will use main roads (36%) more often than route planners (29%) do. These results are shown in Fig. 6.

Special attention is paid to the local roads of type III. This is the lowest category, only intended to provide access to individual lots, the use of which is to be discouraged by through-traffic. Local roads of type III include residential roads, shopping streets, agricultural roads and other roads intended to provide access. Fig. 7 shows the distance share of local roads type III in the planned routes, classified by route planner. A distinction is made between the road use at the origin or at the destination of the trip, and the road use during the trip. The use of local roads type III at the start or at the end of a trip is in accordance with the intended use of these roads, which is providing individual access. However the use of the same category of roads during the trip should be

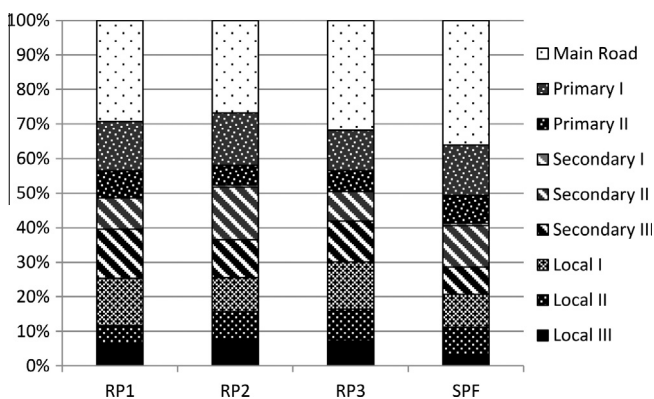


Fig. 6. Percentage of road use by category.

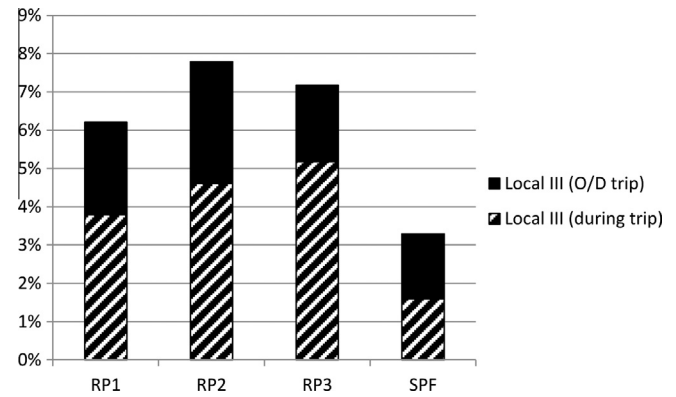


Fig. 7. Percentage of road use in the category local road type III.

considered as cut-through traffic (the hatched part of the column in Fig. 7). The routes calculated by commercial planners will send road users on trips of which (on average) 7.0% of the distance will be travelled along roads of the category local road type III. More than half of the total use of this category occurs during the trip (4.5%). Trips along SPF routes minimise the total use of this category of roads to 3.3%, of which 1.6% occurs during the trip.

5.3. Example route

Typically, SPF routes depart and arrive for the largest part on a local road, using higher road categories in between, as represented by the profile in Fig. 3. As an example we will have a closer look at a particular origin-destination pair in our study area. The studied link originates in Lier and has its destination in Aartselaar, both municipalities located south of the city of Antwerp. As such, this link is tangential with regard to the Antwerp conurbation. This origin-destination pair was chosen based on the complexity level of the link. For the radially oriented commute (from the periphery to the centre), typically an unambiguous route choice can be made. This is quasi-independent from the way in which the route choice is made: by the driver (on the basis of a road map or on the basis of ready knowledge), through a navigation system, or by following official signposting. Moreover a significant portion of the radially directed commute is done by public transport or by bicycle, which is less often the case for tangential commuter trips. The link Lier-Aartselaar is one of the more complex routes in the sample used since large differences in route choice can be observed depending on the applied navigation system, and has an intermediate distance of about 20 km (which corresponds with the average commuting distance in Belgium).

The applied commercial route planners all propose a different route. One of these routes corresponds to the SPF route. The routes are shown in Fig. 8. The map also indicates residential areas. The SPF route attempts to avoid these areas by minimising the use of local roads.

The route profile of the routes proposed by each of the commercial route planners is shown in Fig. 9. The SPF route and Route C are identical and present a profile showing only local road use near the origin and the destination of the trip (19.5% of the route follows local roads). Route B applies a limited use of secondary roads (26.2%), and proposes a route which uses primarily local roads of type I and local roads of type II (70.1%). The profile of route A shows that local roads of type III are used during the trip, but not to give access to the destination point. This route differs from the SPF principles. This route also crosses residential areas in the municipalities of Mortsel and Edegem.

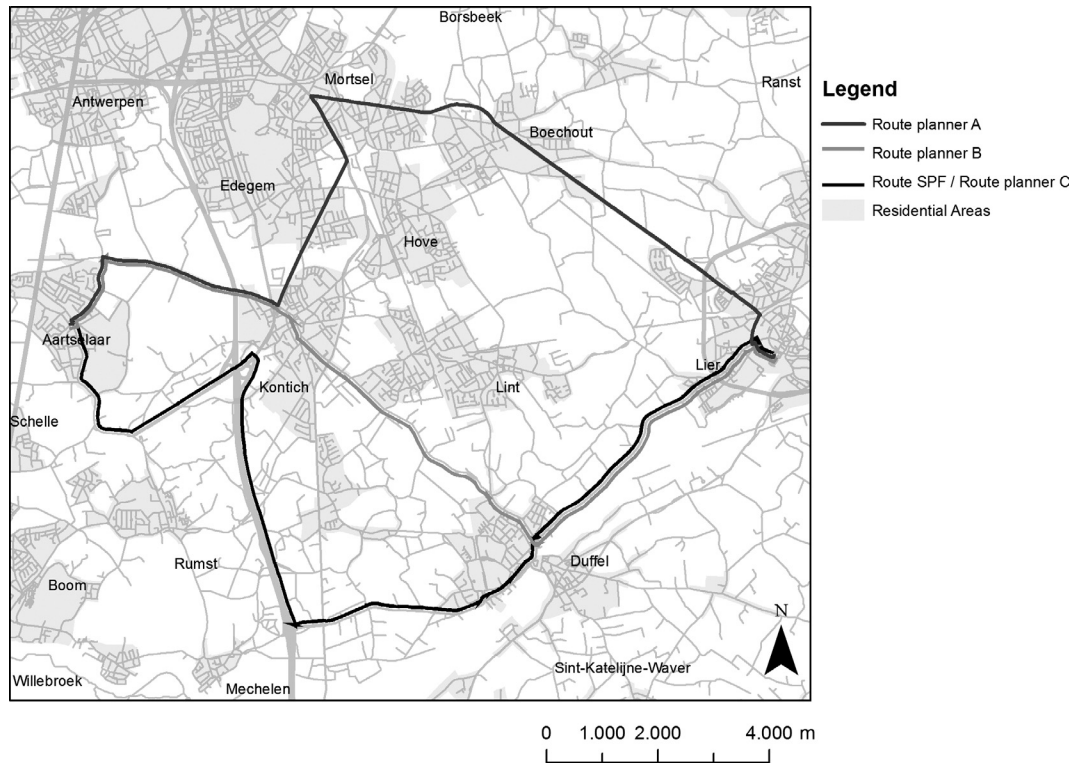


Fig. 8. Lier-Aartselaar route according to different route planners.

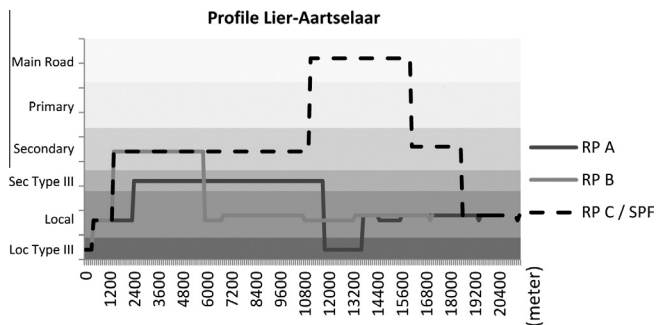


Fig. 9. Profile of Lier-Aartselaar routes according to different route planners.

Route B shows the shortest total distance (17.1 km), followed by route A (19.5 km). The SPF route and route C are both 21.4 km long. The difference in trip duration, 28 min for route A and B and 29 min for route C and the SPF route, is hardly significant.

6. Discussion

Our findings show that the routes calculated according to the SPF road categorisation principles are on average 6.5% longer than routes suggested by commercial route planners. The duration of a trip along an SPF route is slightly longer than the duration of route planners' trips, although limited to an increase of 6 min. SPF based routes make less often use of local roads (21% on average) than routes proposed by route planners (27% on average), and follow main roads more often (36%) compared to route planners (29%) (all measured by kilometres travelled). By applying SPF routes, the use of local roads type III was reduced from 7.0% to 3.3%, while the share of use of this lowest road category in the middle part of the trip (meaning not near the origin or the destination) was reduced from 4.5% to 1.6%. Hence commercial route planners use

local roads more often than is desired from a social point of view. A reduced use of local roads could decrease the amount of traffic in residential areas and may contribute to the liveability of these neighbourhoods.

Based on these findings, we may suggest three possible approaches to address the problem of route choice behaviour, not taking into account liveability requirements. Firstly, the process of redesigning roads in accordance with the assigned category could be accelerated in order to attract or discourage certain types of traffic in a more rigorous way. Drivers as well as route planners are expected to gradually adapt their route choice behaviour to the new situation. Secondly, developers of route planning systems may be required by law not to send through traffic along local roads. Thirdly, the current road categorisation system could be adapted on certain points, making it more in line with expected route choice behaviour by drivers.

At first sight, the first line of thought makes certainly sense, although it is only a solution on the long term. The second line of reasoning assumes that the law should require approval by the competent authorities of the maps used in navigation systems. However, given the rise of hard to regulate open source maps, such as OpenStreetMap, such a course would require an important administrative burden and would therefore be particularly difficult to implement.

Regarding the third approach also new interpretations of the road categorisation in Flanders may be considered, with enhanced attention to road safety, multimodal use, multiple functions of main roads in urban areas, etc. This may influence the socially desired route due to the addition of new features and parameters to the routing algorithm. Another good reason to adjust the current road categorisation would be that a strict application of the intended use of the various categories may lead to implausible 'socially desired' routes, for example, by avoiding a main road for making a local trip, although this main road is commonly known to be the most appropriate route choice.

Another drawback of route choice influenced by road categorisation is the static nature of the system. If an incident or congestion occurs along a socially desired route, an alternative route will be detected along the local road network. However it is unclear if an SPF based routing method is able to make the adjacent road network 'accessible' in case a road link is blocked. The study "Cut-through traffic in the south-east fringe of Antwerp" (Keppens et al., 2007) shows that SPF road categorisation is unable to provide a solid basis to deal with traffic in congested networks. Further research is needed to include dynamic routing options, in addition to normal traffic situations.

Local governments need to be aware that their role in the provision of road data will become more important in the near future. The European ITS Action Plan (EC, 2011) acknowledges this challenge by creating minimum requirements and procedures for ensuring the availability of accurate public data for digital maps. More cooperation between public bodies and digital map providers may be helpful in achieving these.

This study should be viewed as a starting point for examining whether liveability guided route navigation is feasible, and if existing policies of road categorisation and other environmental parameters (e.g. presence of schools) may be part of such a strategy. After all, route planning straight through residential and other sensitive areas is in most cases not a sustainable option.

7. Conclusion

This study aims to reveal to what extent route choices made by commercial route planners differ from the socially desired routes, as defined by the road categorisation system of the leading spatial policy plan in Flanders (SPF). Particular attention is paid to the intensity of the use of local roads by through-traffic. The method is based on an analysis of the share of each road category used along routes generated by commercial route planners. A comparison of these routes with socially desired SPF routes illustrates differences in road category use and highlights the perhaps excessive use of local roads by through-traffic due to the common application of route planners.

Results show that commercial route planners' routes use roads of the lowest category more often than desired. Nevertheless, for some of these routes, the socially desired route is a feasible alternative, which is not excessively increasing time consumption or distance travelled. The implementation of the prevailing road categorisation system in Flanders in routing algorithms has the potential to promote more sustainable route choices, while infrastructural measures that discourage cut-through traffic may help materialise the categorisation system.

Finally, policy recommendations follow three different tracks: redesigning roads, incorporating road categorisation in the internal map of route planners, in combination with a more pragmatic approach of the principle of road categorisation can lead to a more responsible use of road networks.

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